S&A FY03 Annual Review Meeting

On-Line Molecular Analysis for Improved Industrial Efficiency

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Overview

- **Project Description: Real-time molecular analysis based on Transient Infrared Spectroscopy (TIRS)**
- **Objectives: Demonstrate TIRS on industrial processes in several IOF industries**
- **Overall goal: Increase industrial efficiency**

Technical Merit/Need

- Molecular processes are involved in 7 of the 10 IFOs including Agriculture, Mining, Petroleum, Forest Products, Chemical, Glass, and Supporting Industries
- Real-time, on-line molecular analyses can lead to improved efficiency in each of these industries

Technical Merit/Need cont'd

- Molecular processes, from feedstock to finished products, can often be optimized if molecular composition is continuously sensed on-line and in real-time for automated process control.
- Currently, most molecular material analyses are done in the laboratory after production rather than during which does not serve process control needs.

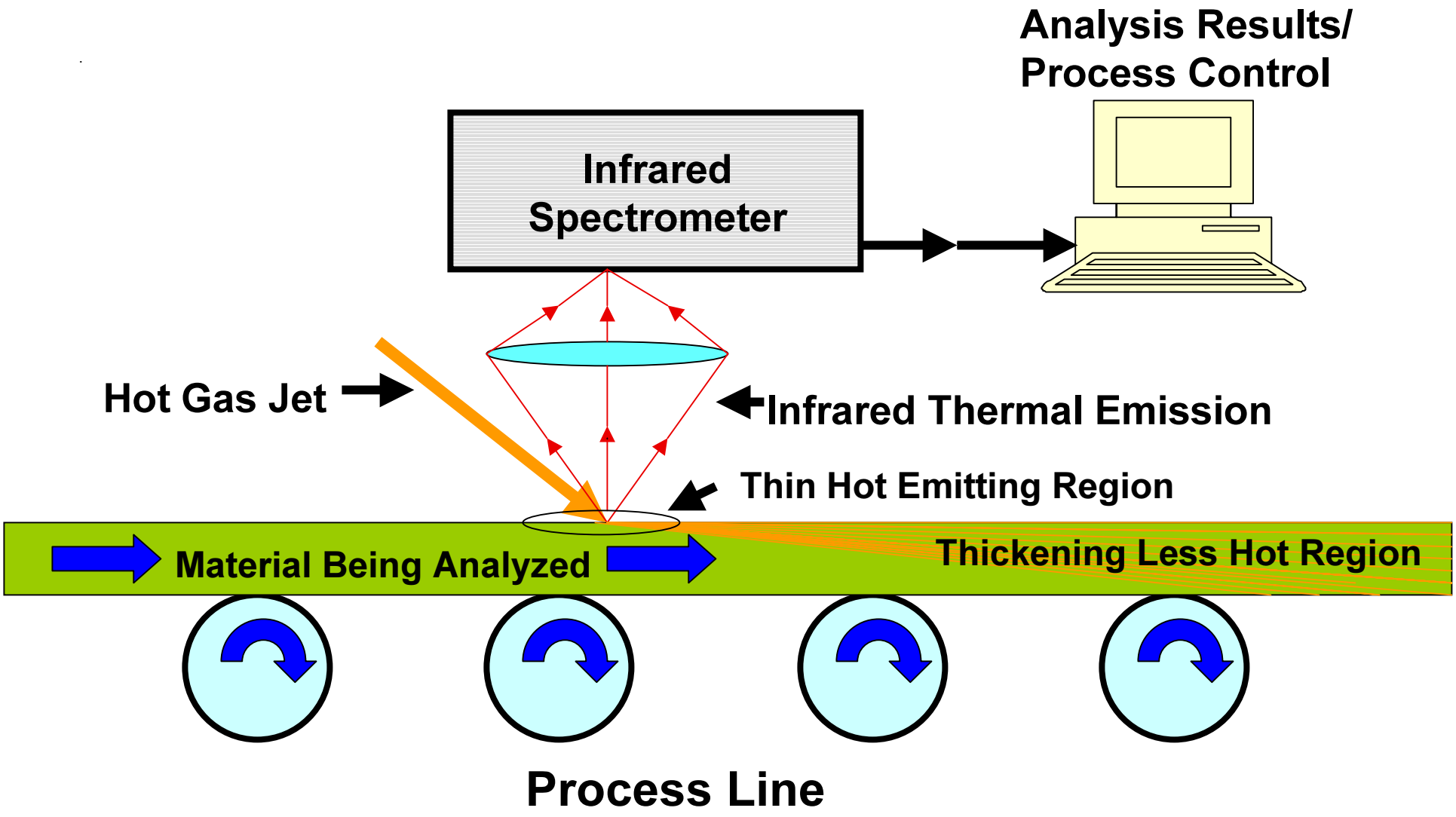
Technical Merit/Need cont'd

- Infrared molecular spectroscopy is widely used in industrial laboratories for molecular analysis.
- It is difficult to apply to on-line measurements using conventional methods due to their need for pre-analysis sample preparation to reduce the opaqueness of most samples.

Technical Merit/Contribution

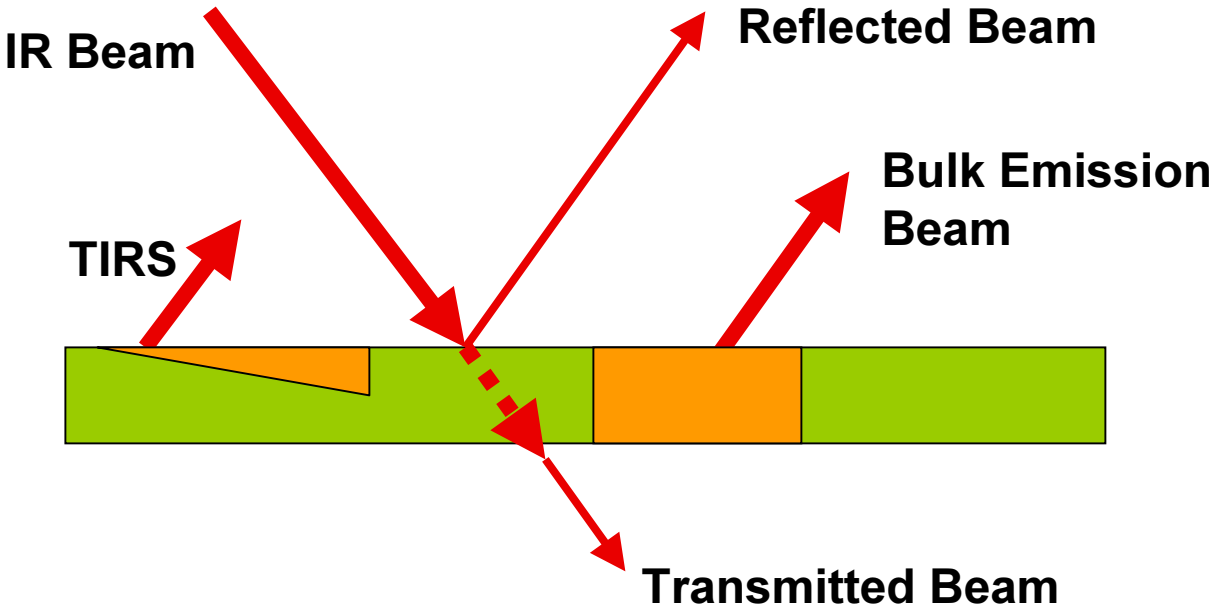
- Our innovation is to use the motion of the process line and the diffusion time of heat as it propagates into the sample to isolate in time a thin non-opaque layer of the sample for molecular analysis in real-time.
- This approach, called Transient Infrared Spectroscopy (TIRS), allows a thin-layer thermal emission spectrum of the material to be measured, which contains all of the molecular information provided by a conventionally measured infrared spectrum.

How Does TIRS Work ?

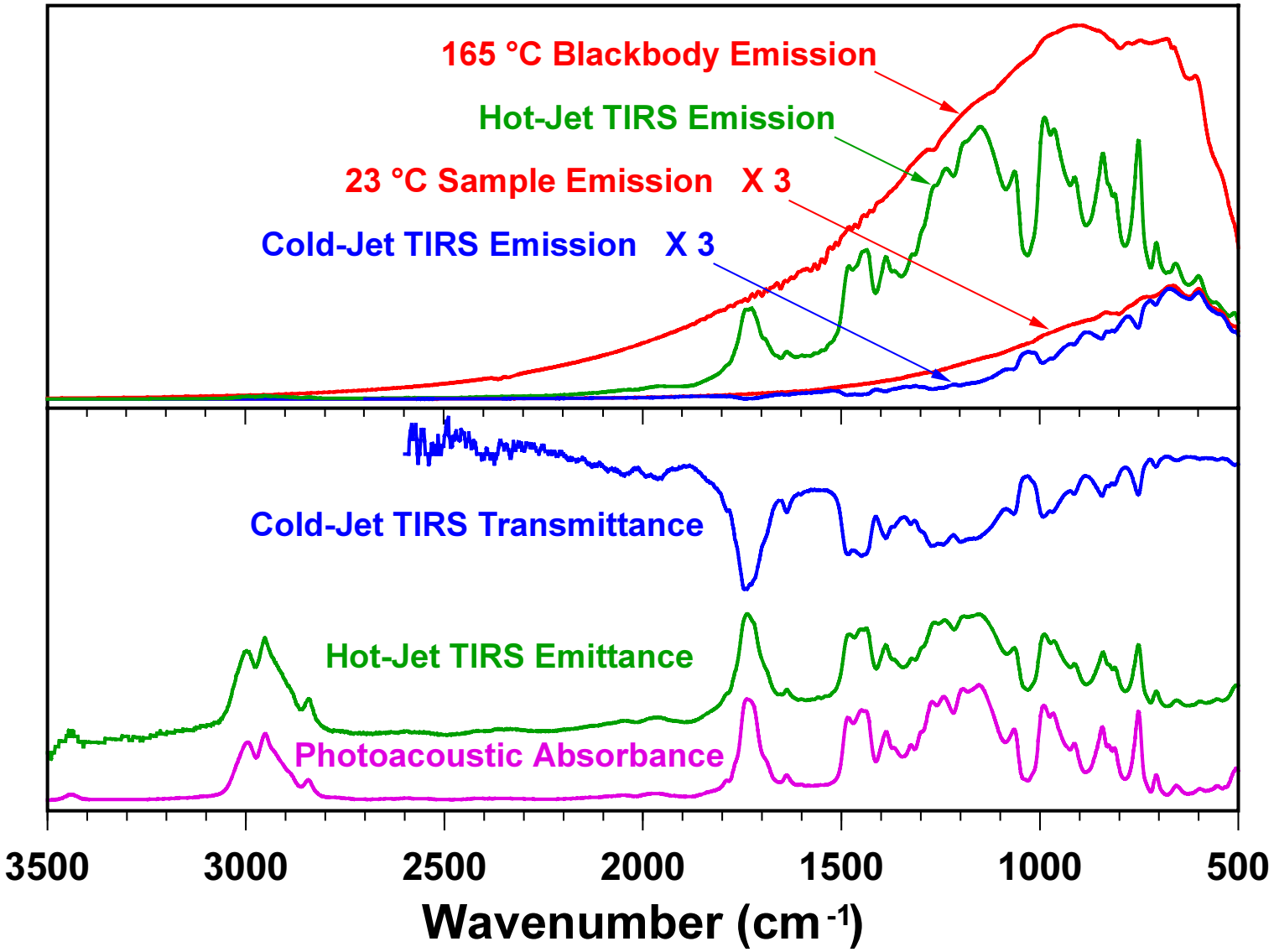


How Does TIRS Compare to Conventional Methods

- Transmission, reflection, and emission spectroscopies



IR Spectra of PMMA



Where Can TIRS Be Used?

- On process lines that operate from high to low temperatures
- At line speeds from slow to very fast
- On processes running single fibers, irregular shaped flowing materials, viscous or nonviscous liquids, and nearly any sheet stock
- On process lines where noncontact remote sensing is desired

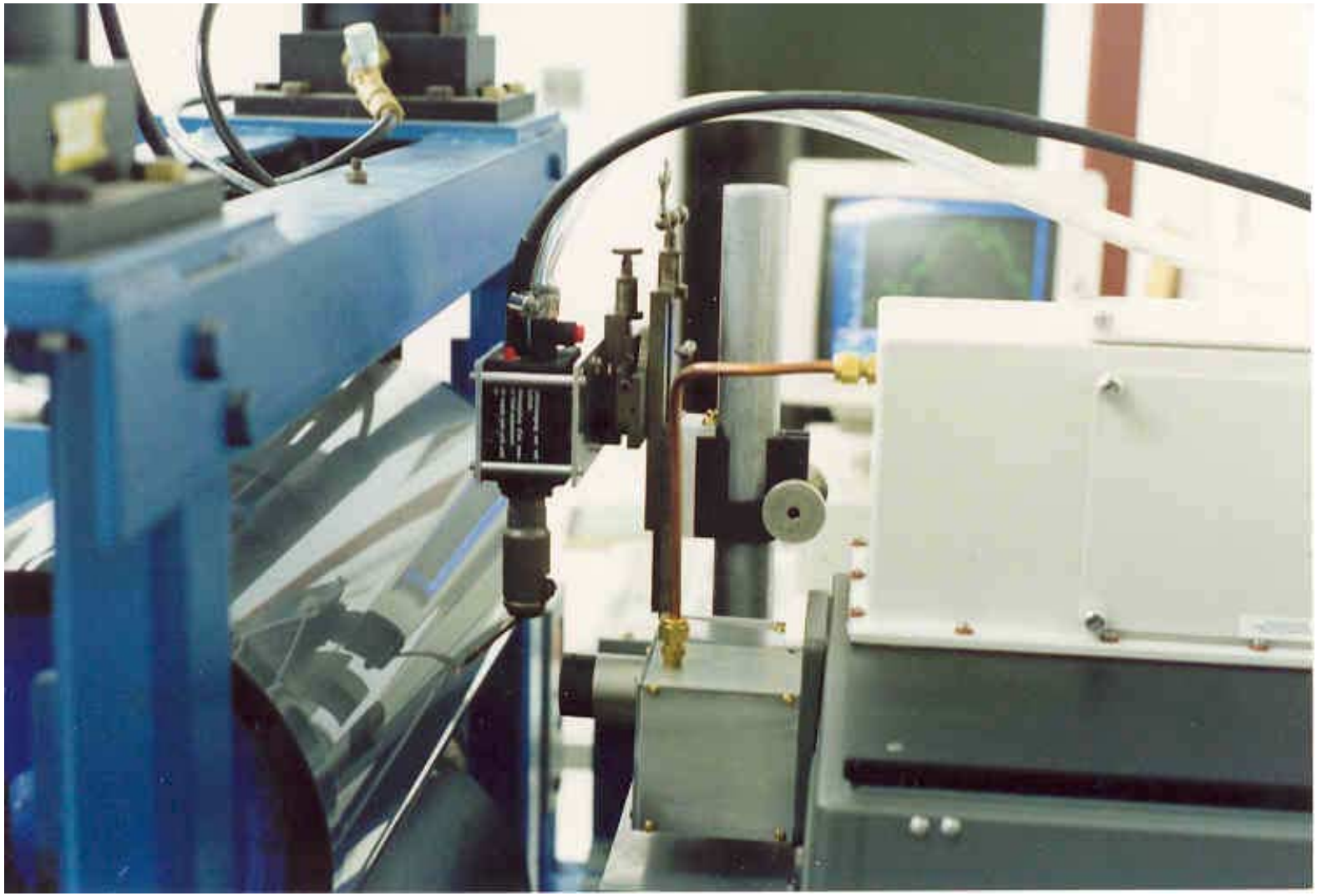
What Does TIRS Measure?

- Molecular composition of a wide range of materials
- Cure or polymerization of coatings
- Layer thicknesses of layered materials
- Copolymer, filler, and additive concentrations in engineering polymers
- Other material properties, such as mechanical, related to molecular composition

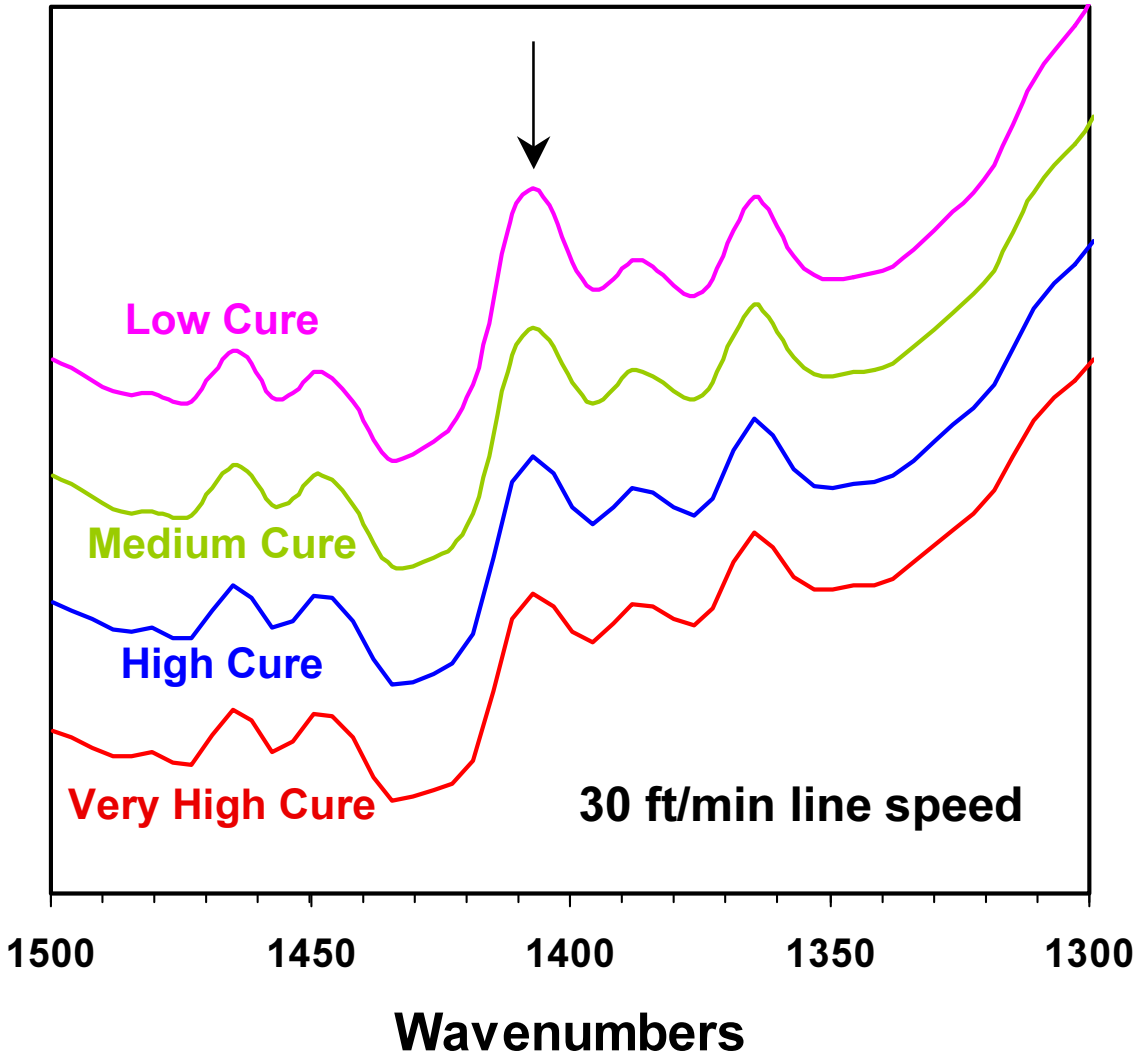
Examples of TIRS Applications

- Monitoring cure of acrylic coating applied to plastic sheet stock (Petroleum and Chemicals Industries)
- Fiber-optic cladding and jacket cure monitor (Glass Industry)
- Wood chip chemical composition monitor (Forest Products Industry)

Acrylic-Coating Cure on Plastic Sheet Stock – GE Plastics

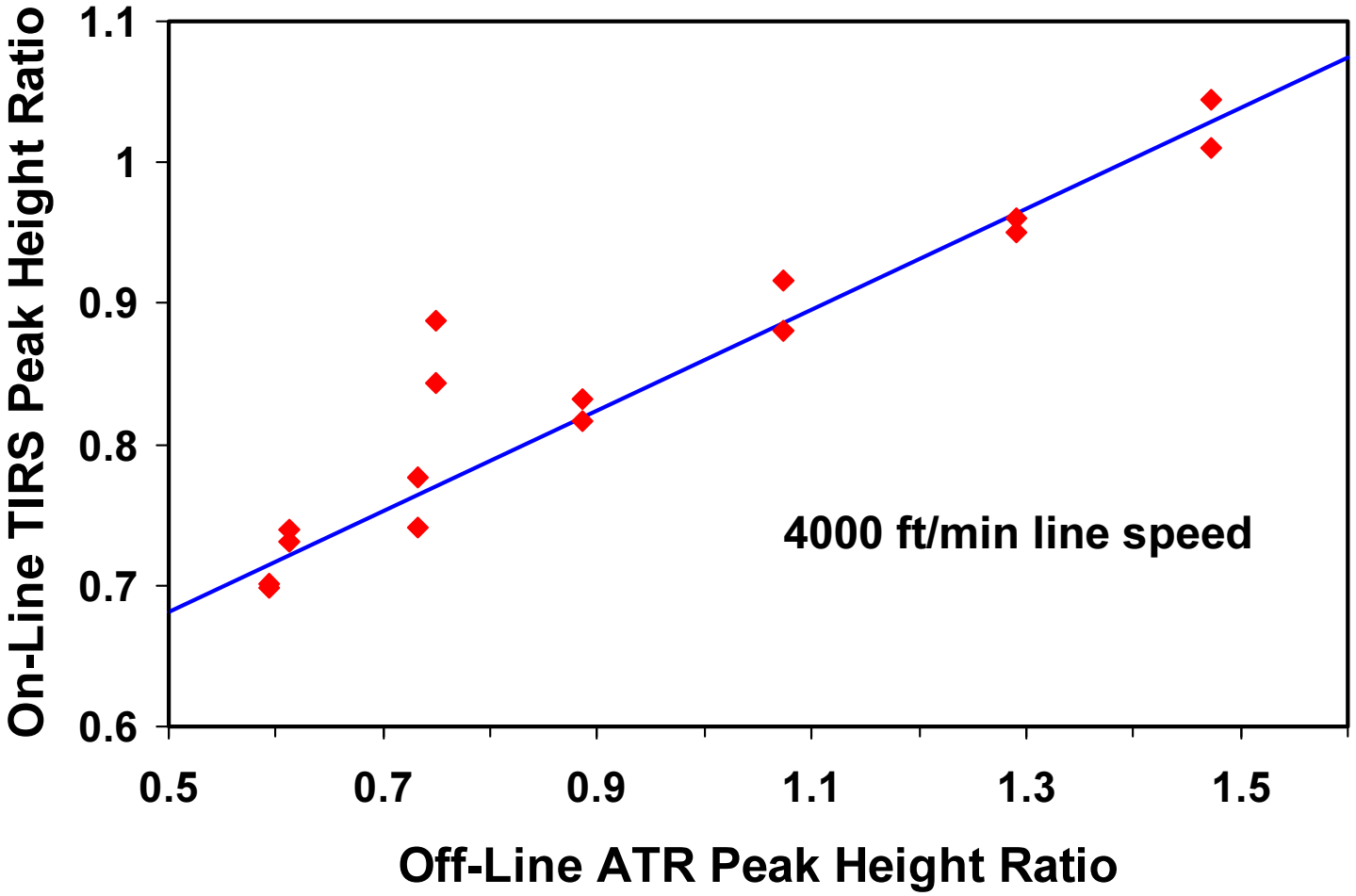


Acrylic-Coating Cure on Plastic Sheet Stock – GE Plastics

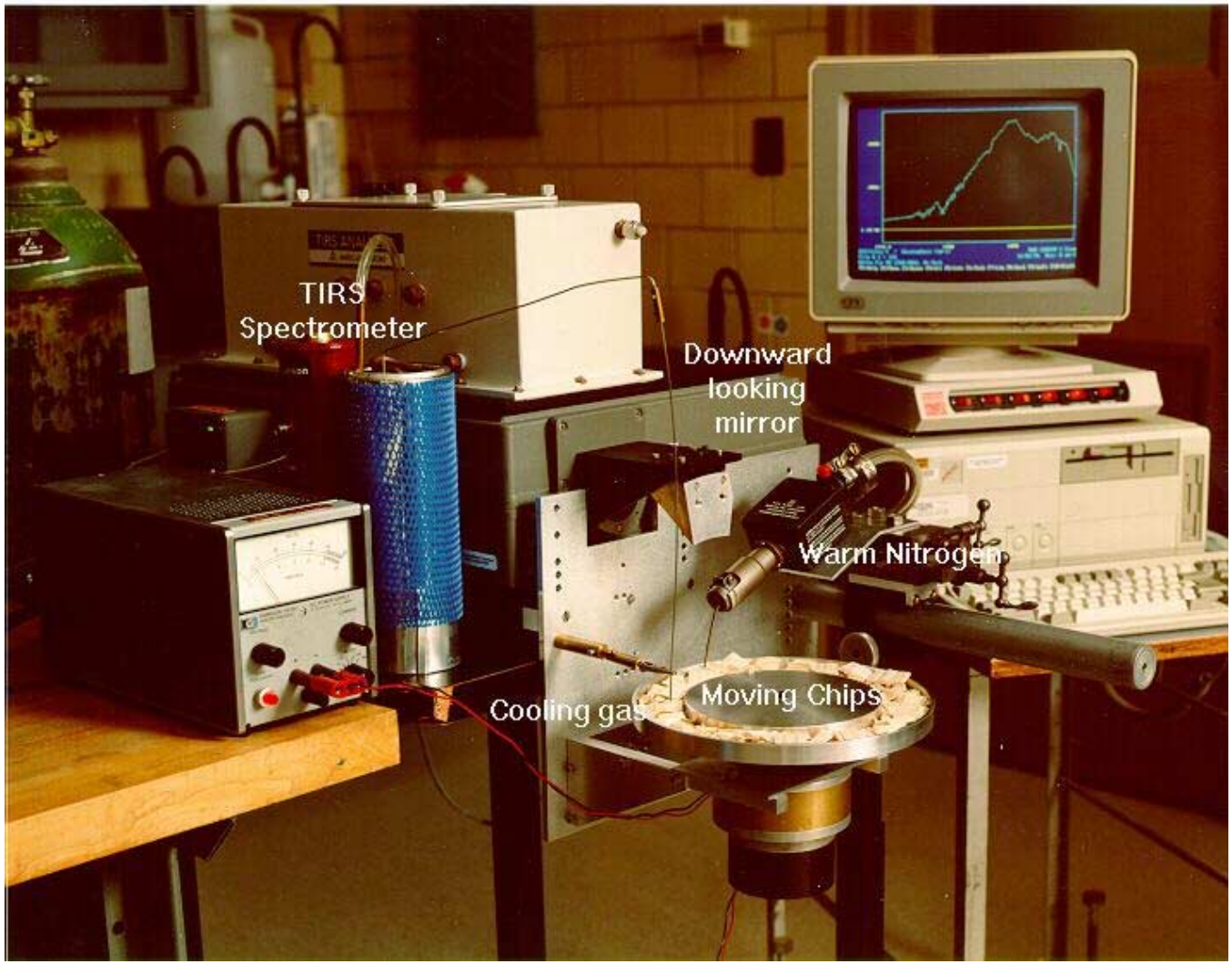


Fiber-Optic Cable Jacket Cure - Corning

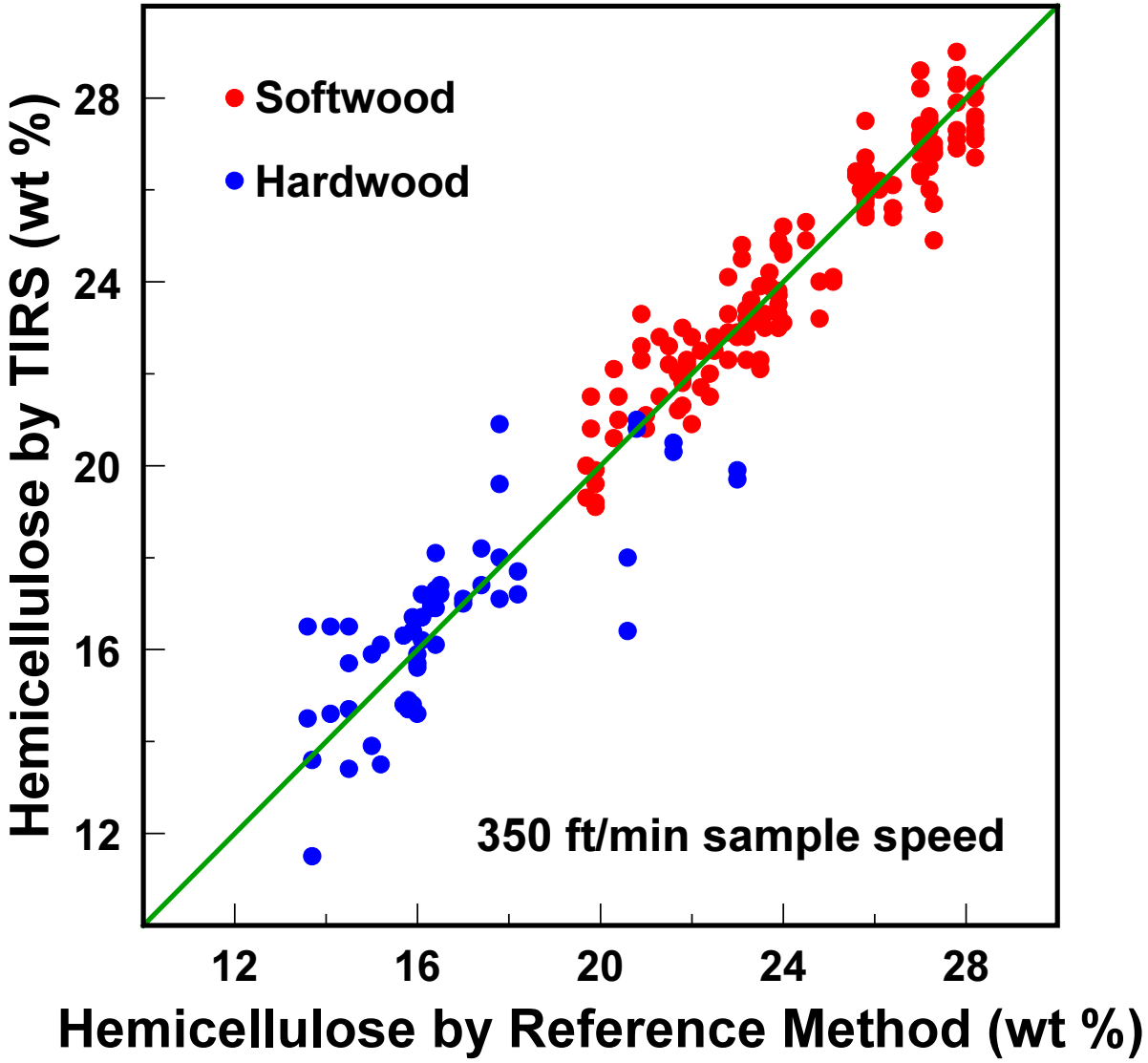
Fiber-Optic Cladding Cure - Corning



Analysis of Moving Wood Chips



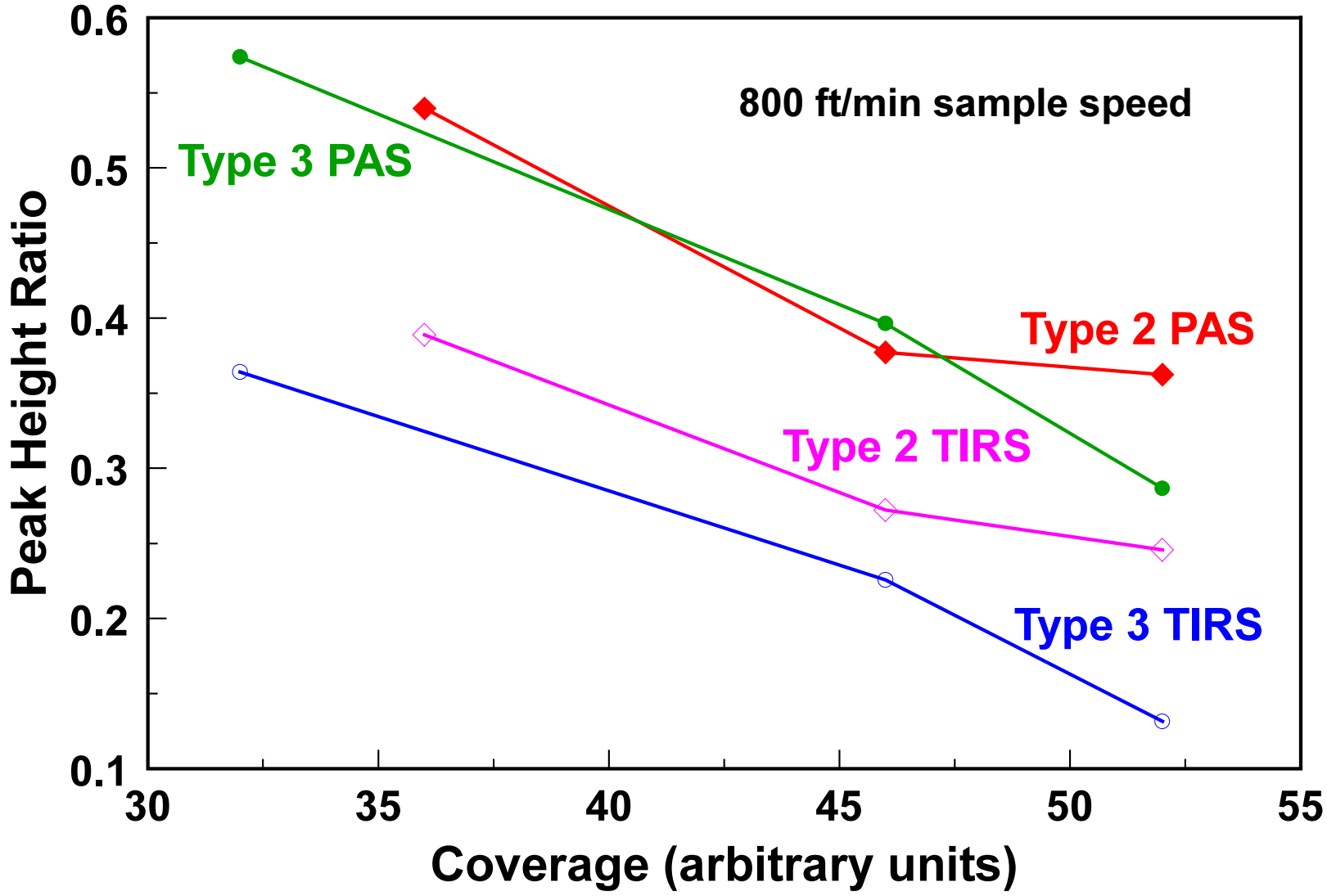
Hemicellulose of Wood Chips



Technical Progress and Outlook

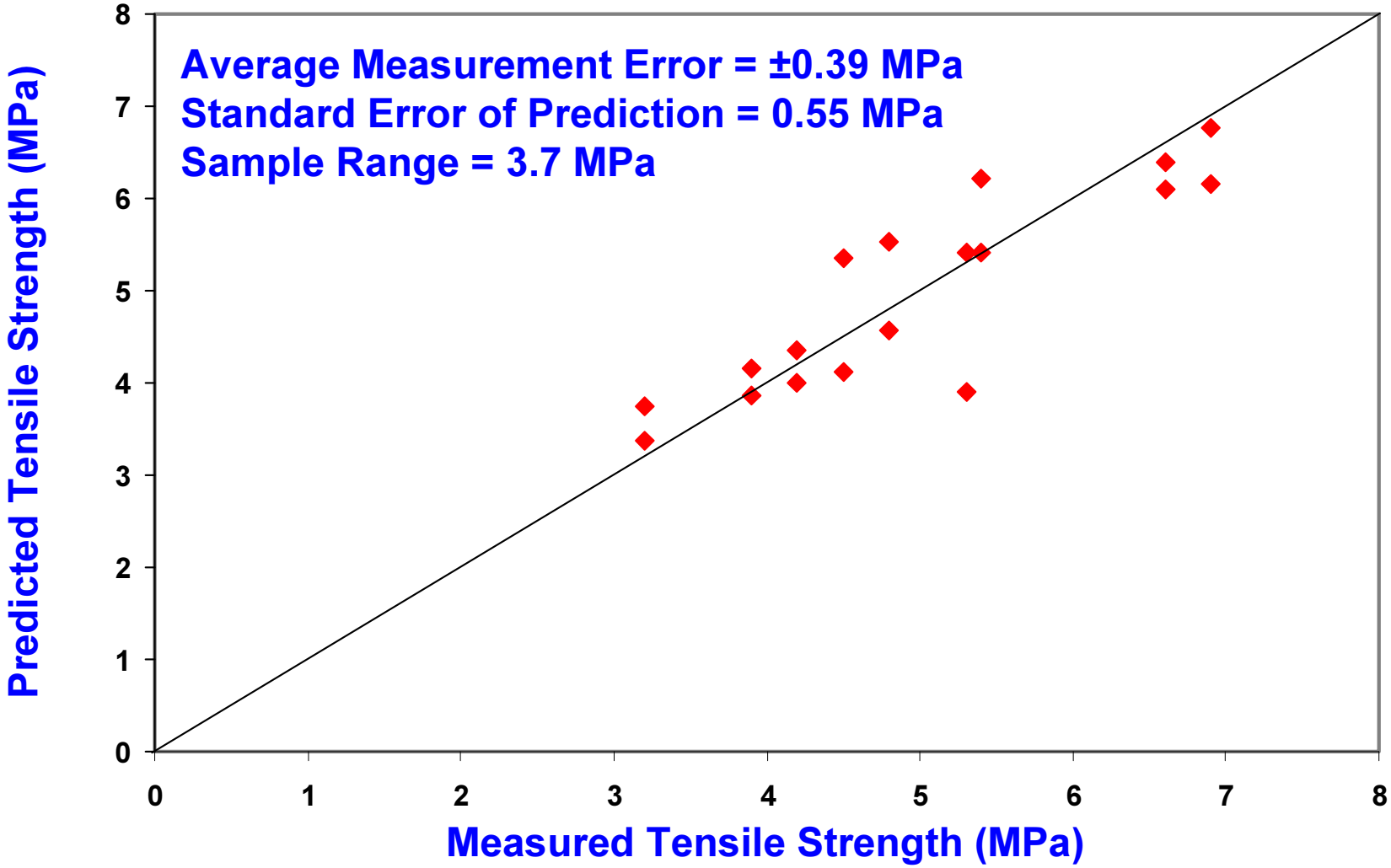
- Sensing thin-layer thicknesses on sheet stock – Kodak (Chemical)
- Monitoring cross-linking of biopolymers processed by reactive extrusion – Dept. of Food Science, Iowa State University (Agriculture)
- Monitoring the formulation engineering polymers at the extruder output – GE Plastics (Chemical and Petroleum)
- Detecting “sinker” wood in window frame manufacturing (unsuccessful) – Pella Window Corp. (Forest Products)

Layer Coverage vs. TIRS Peak Ratio - Kodak



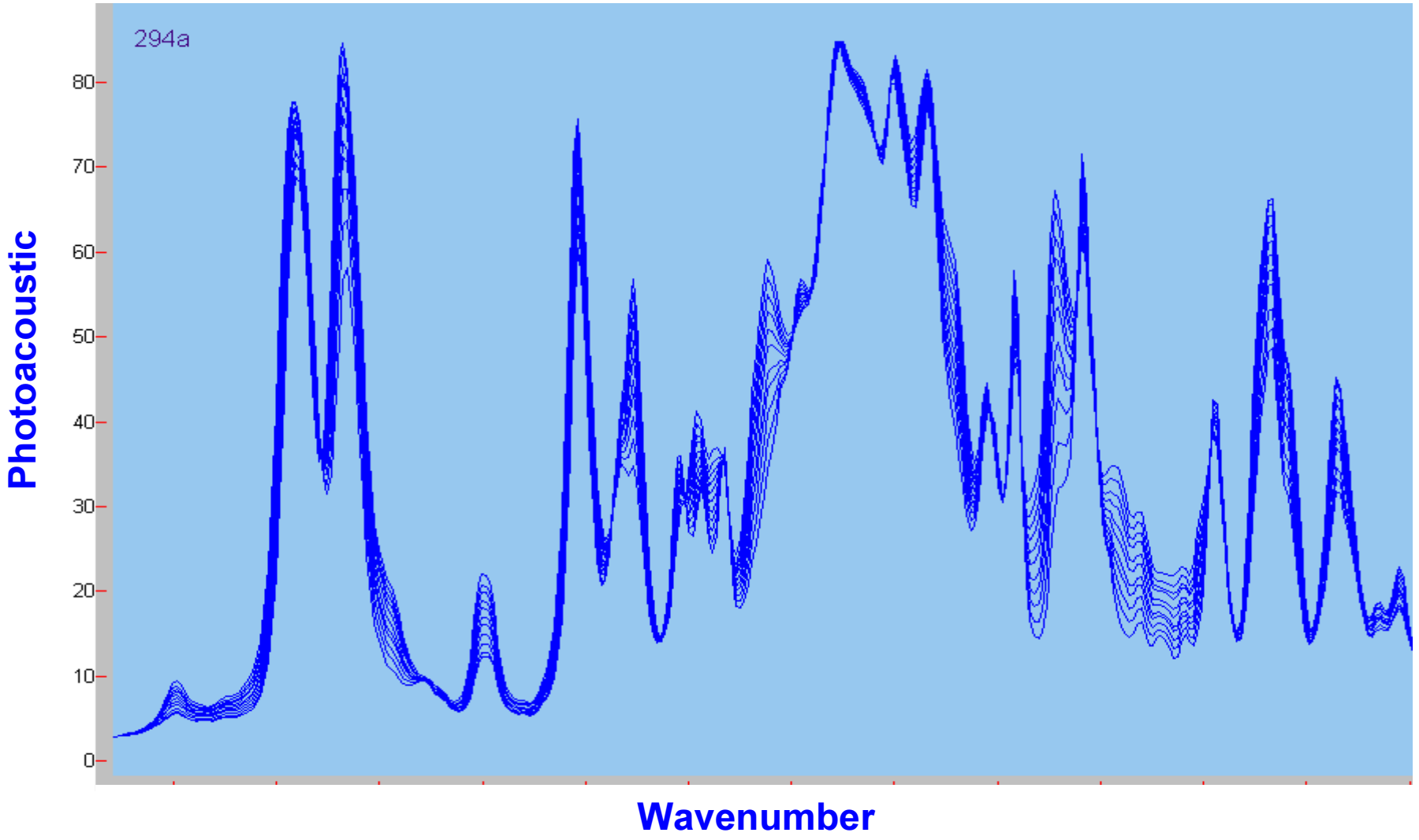
Cross-Linking of Biopolymers

Tensile Strength of Soy Plastics Containing Modified Rubber Additive

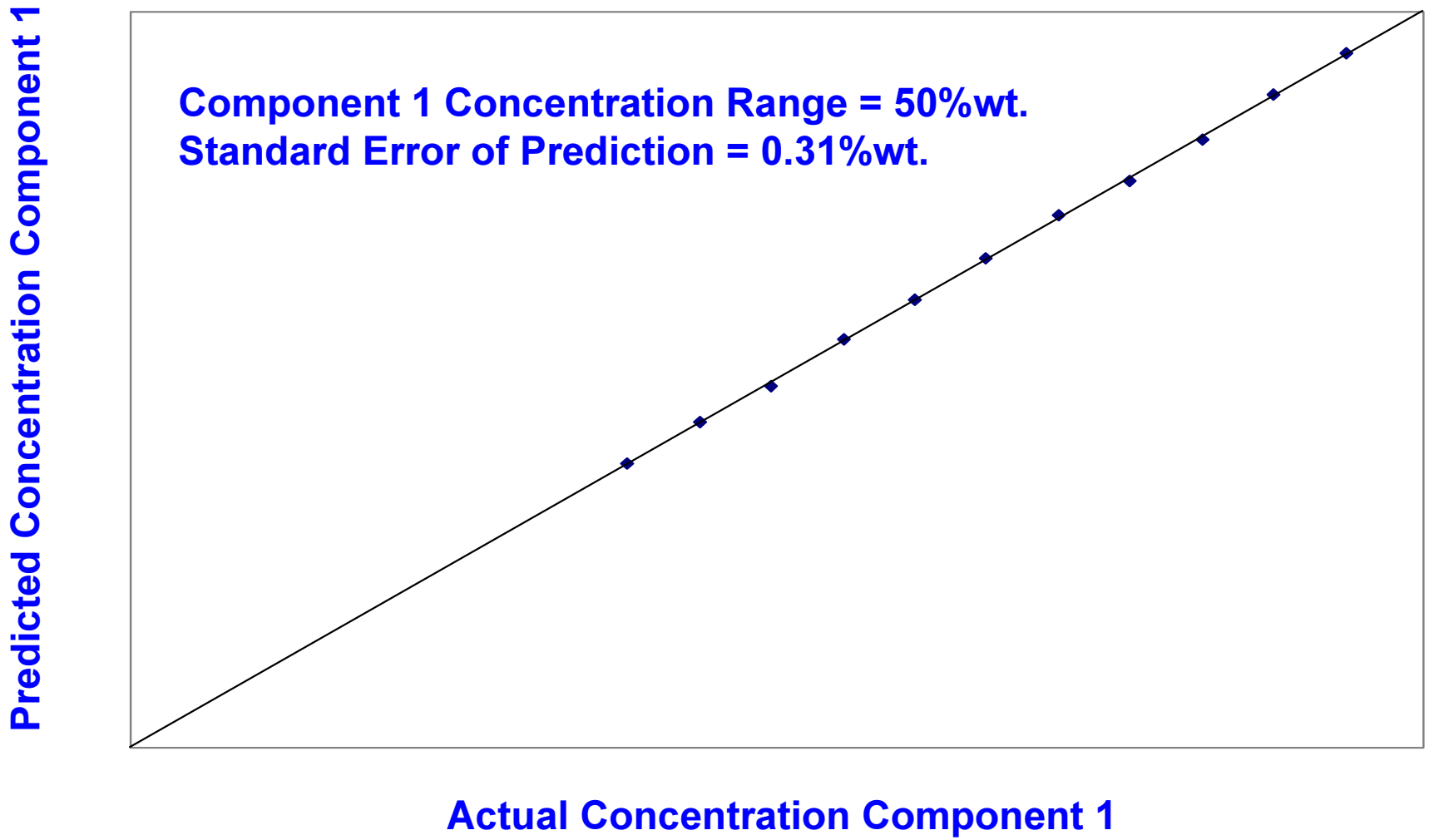


PAS System for TIRS Feasibility Tests

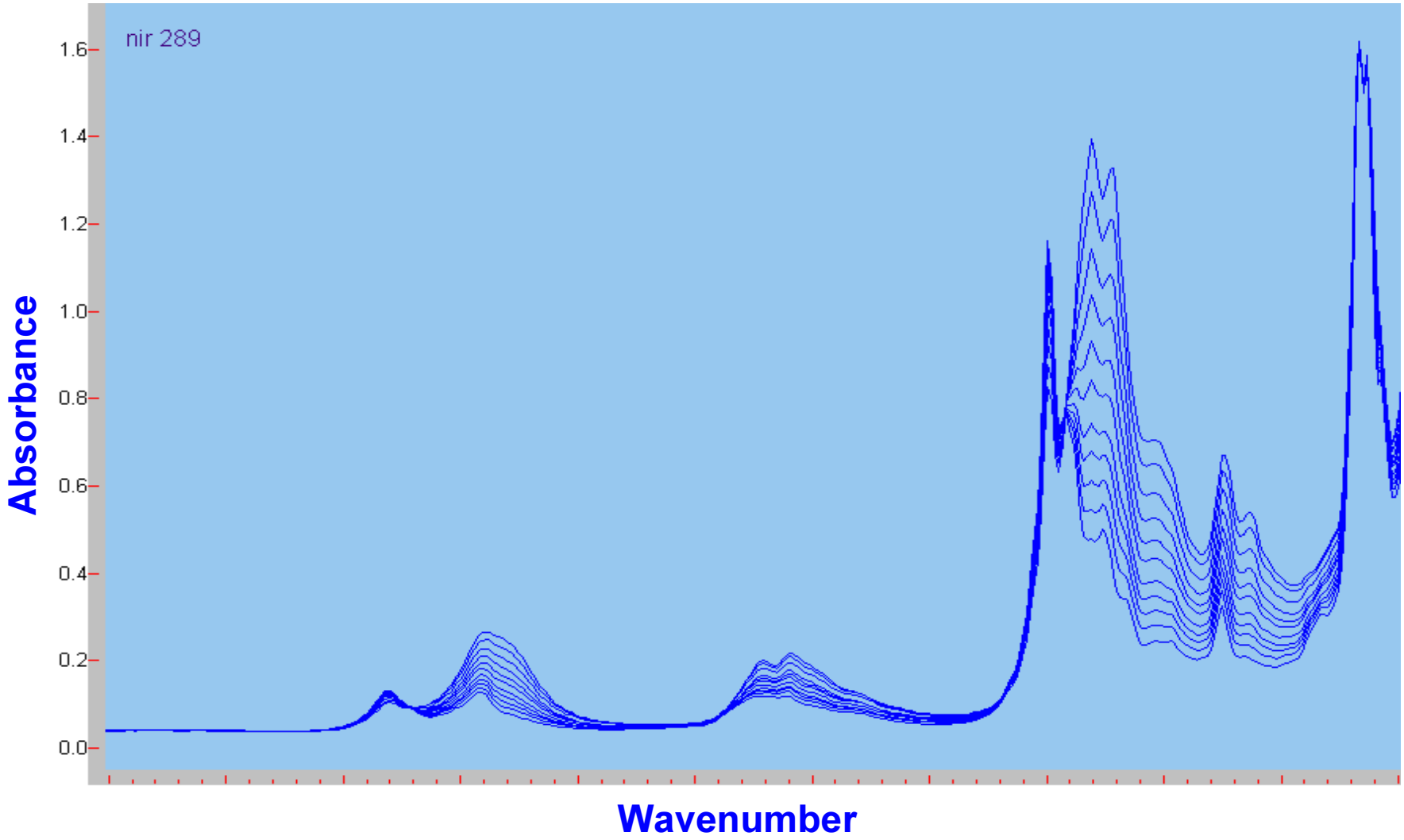
Photoacoustic Spectra of GE Polymer Blend



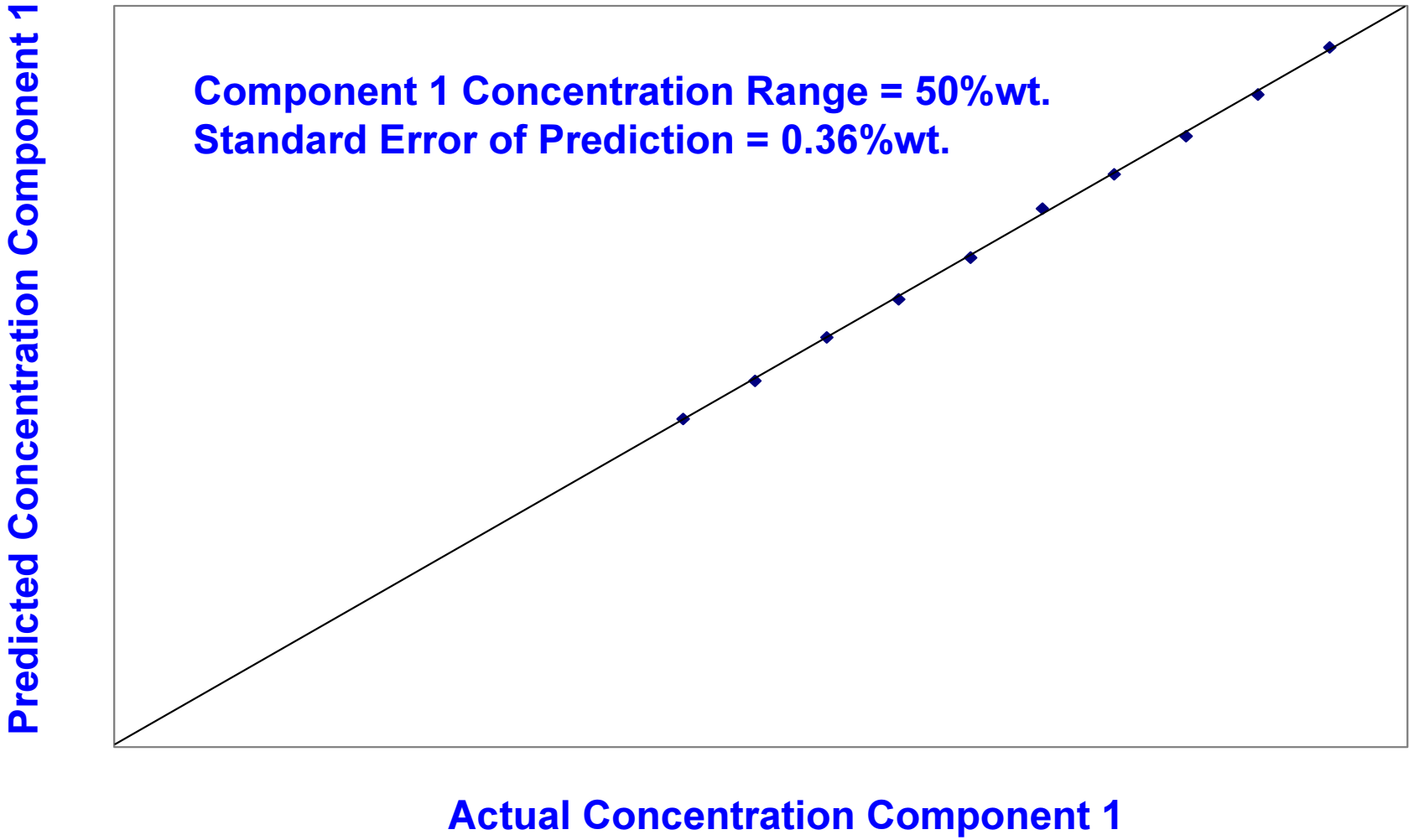
Prediction of Component 1 Concentration in GE Polymer Blend from Photoacoustic Spectra



NIR Spectra of GE Polymer Blend



Prediction of Component 1 Concentration for GE Polymer Blend from NIR Spectra



Technical Progress and Outlook

Future Technical Milestones/Goals

Milestone/Goal	Expected date of completion	Comments
Kodak site test/roll stock line	9-30-03	PAS & TIRS pretests done
GE/Mount Vernon site test/extruder line	9-30-03	PAS pretest in progress
GE/Selkirk site test/ extruder line	??	Need $

Technical Progress and Outlook

Possible Barriers:

- Misperceptions of process engineers
- Continuity of funding

Industrial End-User Involvement:

- Kodak
- GE Plastics (Mount Vernon and Selkirk)
- Pella Window

Industrial involvement arranged through PI's contacts in the research community

Market Potential

- **Commercialization Plan:**

  Partnership between ABB Bomem and MTEC Photoacoustics
- **IOF Areas of Applicability:**

  Agriculture, Mining, Petroleum, Forest Products, Chemical, and Supporting Industries are all molecular in nature
- **What's Next:**

  Continue to demonstrate technology and to seek industrial installations

Programmatic Merit

(In the case of polymers)

Energy Benefits:

Polymer processing consumes close to 1000 quads/year (Ashby,1992) so increases in efficiency can be significant

Economic and Environmental Benefits:

Better control of polymer processing increases quality and reduces waste

M.F. Ashby, Materials Selection In Mechanical Design, Pergamon Press, 1992.

Summary

- TIRS has the potential to increase general process efficiency and thus reduce energy and feedstock use, improve product quality, and reduce waste.
- TIRS is applicable to all of the "molecular" IOFs including agriculture, mining, petroleum, forest products, chemical, glass, and supporting industries.